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TARGET DETECTION USING BLACK-AND-WHITE TELEVISION

STUDY II: DEGRADED RESOLUTION AND TARGET-DETECTION PROBABILITY

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ABSTRACT

This study used a black-and-white closed-circuit television (TV) system to investigate the effects of two levels of TV resolution (800 and 450 lines) on the probability that subjects would detect an M-48 tank. While a previous study used horizontal degradation only, this one degraded the TV image in both horizontal and vertical dimensions.

The tank was shown in each of nine areas of the TV screen, under both levels of resolution. Thirty subjects observing the TV monitor were asked to indicate in which of the nine areas the tank appeared.

With changes in the horizontal resolution only, in the previous study, changing resolution from 800 to 400 lines did not affect target-detection probabilities significantly. But with both horizontal and vertical changes, subjects performed significantly better at the 800 level of resolution than at the 450 level. The tank's location on the TV screen, although confounded with other variables, appeared to have an important effect on target-detection probability.

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TARGET DETECTION USING BLACK-AND-WHITE TELEVISION

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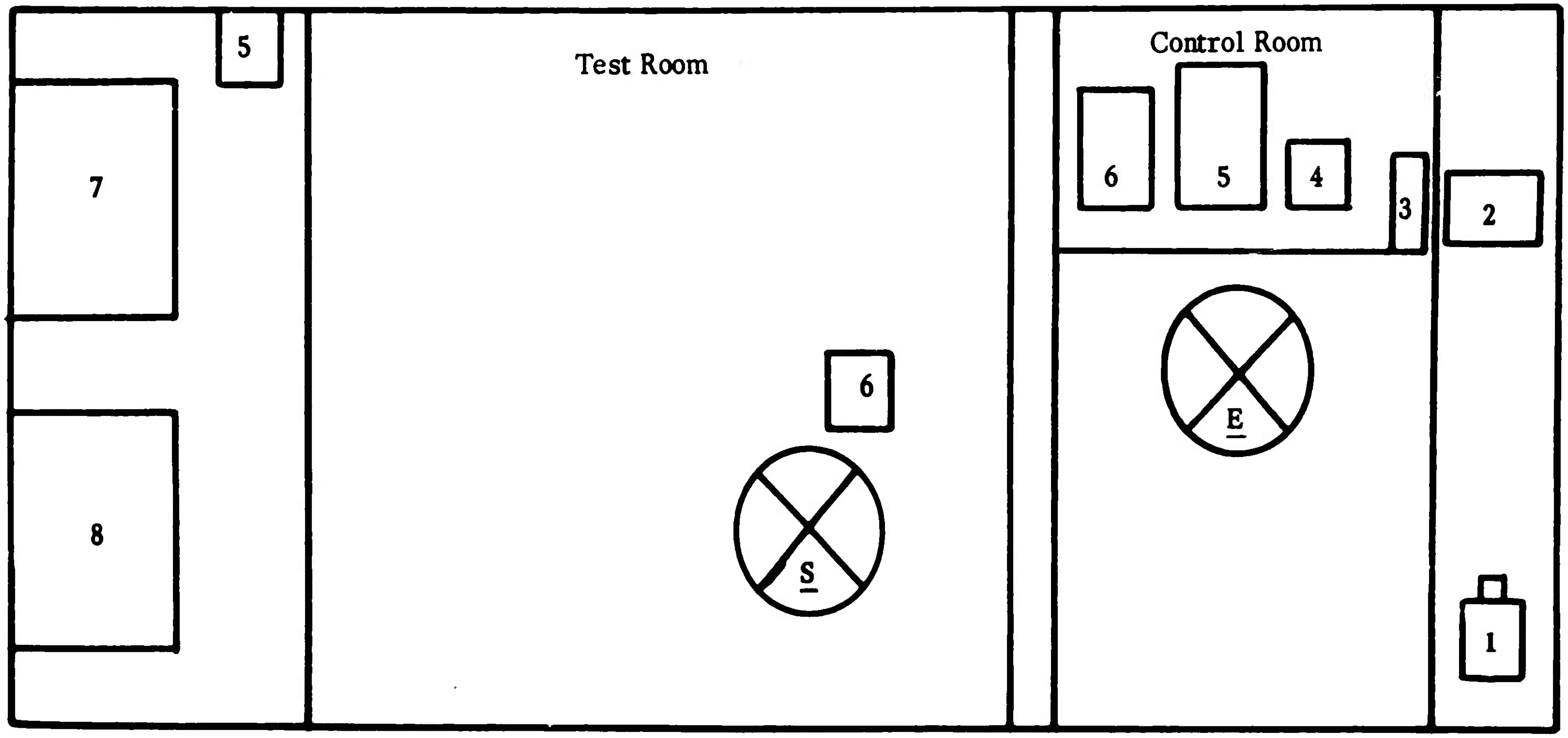
INTRODUCTION

In some military applications of television (TV) operators must detect and identify targets on the TV display. Gordon (2) has pointed out two important aspects of the combat situation: target detection and target identification. Target detection ordinarily refers to an observer's ability to determine the presence or absence of a man-made object. Target identification, on the other hand, refers to the observer's ability to characterize or specify the object he has detected.

In a preliminary study, Oatman (3) compared target-detection scores from a projected-slide display and a TV display. Superior performance on the slide display was interpreted as being due to its better resolution. Freeberg (1) found that reducing the information on a video screen increases form thresholds significantly. In a more recent study, Shanahan (5) found that reducing the bandwidth of a closed-circuit TV system likewise reduced subjects' ability to identify targets.

Oatman (4) recently investigated the probability of detecting an M-48 tank at four different levels of TV resolution. The subjects performed about equally well at 800, 600, and 400 lines of resolution, but their performance was significantly poorer with the 300 level of resolution. He suggested that they may have performed equally well at the three higher levels because the resolution was reduced in the horizontal plane only; the vertical resolution was unchanged.

The present study measured the effects of changing both horizontal and vertical resolution on the target-detection probability with a black-and-white closed-circuit TV system.



1. TV Camera
2. Foto-Video F-101A TV Light Box
3. Hunter Interval Timer
4. Standard Timer
5. Intercom
6. Response Panel
7. 14-Inch TV Monitor
8. 21-Inch TV Monitor

Fig. 1. ARRANGEMENT OF EXPERIMENTAL TEST AND CONTROL ROOMS

METHOD

Subjects

Thirty male enlisted men from the U. S. Army served as subjects (Ss). The Ss' ages ranged from 17 to 24. The Ss' vision (corrected or uncorrected) ranged from 20/29 to 20/13 as measured by Ortho-Rater tests.

Apparatus

Television

The equipment for the television presentation was a General Precision Laboratories P.D.-601 closed-circuit high-resolution TV system. The TV camera was placed in a control room which fed radio-frequency (RF) signals to a 14-inch monitor and a 21-inch monitor in an adjacent test room. A Foto-Video F-101A light box, holding one 8" x 10" positive-transparency photograph, was placed in front of the TV camera.

Both TV monitors in the test room were divided into nine equal areas by black thread. The Ss used a response panel with nine buttons. The response panel was also marked into nine areas by thin strips of masking tape. Each button on the response panel represented one of the nine areas on the TV monitor. The control room contained a similar panel which indicated the Ss' responses.

The amount of time that a picture remained on the TV monitor was controlled by a Hunter interval timer, model 100-C, series D. A Standard electric timer recorded the Ss' response times. An intercom provided communication between the test and control rooms. Figure 1 shows the experimental arrangements.

Picture Degradation

Two levels of TV resolution (800 and 450) were used in this experiment. The 800 level was the normal number of scan lines per frame in the picture displayed on a 14-inch monitor. The degraded picture (450) was obtained by using a different size monitor and moving the light box farther away from the TV camera. Normally, the 21-inch and 14-inch monitors would present two different sizes of TV displays. However, by moving the light box away from the TV camera, the size of the image on the 21-inch monitor can be reduced so it coincides with the normal image on the 14-inch monitor. Moving the light box reduces both horizontal and vertical resolution. Two large pieces of black cardboard,with a cut-out the size of the 14-inch monitor, were placed in front of both TV monitors. Thus when the S viewed the TV screen, he could not tell which monitor he was observing. The cardboard in front of the 21-inch monitor also masked off the unused portions of the TV screen. The amount of picture degradation (800 and 450) was measured with a standard RETMA TV test pattern, and these levels refer to resolution in the center of the TV screen.

Procedure

After S was checked for visual acuity, he was seated approximately 72 inches from the TV screen, instructed, and given the response panel. Each S was shown ten 8" x 10" photographs, nine showing an M-48 tank (one in each area) against a homogeneous background and one showing only the background. The tank was 3/8" long and 3/16" wide as it appeared on the two TV monitors, and it subtended a visual angle of 18 minutes.

Every S saw the ten photographs four times under both levels of picture resolution. The photographs were presented in a random order, identical for all Ss. One half of the Ss began with the 800 level of resolution, while the other half began with the 450 level of resolution. The Ss completed their observations on one monitor before making their observations on the second monitor.

The TV monitor was illuminated continuously. When the experimenter started the interval timer, it transmitted the picture from the control room to the Ss' monitor in the test room for a 0.5-second exposure.

The S's task was to press the response-panel button that corresponded to the area where he saw the target on the monitor. The S was told to push any two buttons when the blank slide was presented, indicating that he saw no target on the screen. The instructions are given in the Appendix.

RESULTS

The criteria of Ss' performance were response times and detection errors. Response time was defined as the time between a target's appearance on the TV screen and the S's response. A detection error was failing to locate the target correctly. In scoring, one point was allowed for each correct detection.

A constant value of one was added to all treatment-by-subject cells to avoid blank cells in the analysis. This procedure raised the means by one but did not affect the variance.

Tables 1 and 2 present the means and standard deviations for the correct detection scores and response times as a function of picture degradation. The analysis of variance indicates that detection scores for the two resolutions differed significantly ($p < .01$). However, the different resolutions did not affect response time significantly.

TABLE 1

Means and Standard Deviations for Correct Detection Scores as a Function of Resolution (N = 270/cell)

	Resolution	
	800	450
Mean	4.80	4.00
Standard Deviation	.57	1.28

TABLE 2

Means and Standard Deviations for Response Times as a Function of Resolution (N = 270/cell)

	Resolution	
	800	450
Mean	1.41	1.68
Standard Deviation	.40	.49

The analyses of variance of the detection scores and response times are summarized in Tables 3 and 4. Both main variables, resolution and location, were significant ($p < .01$) with the correct detection scores and with response times. All of the interactions were significant ($p < .01$) for the correct detection scores, but only the resolution-by-subjects interaction was significant for the response times.

TABLE 3

Summary of Analysis of Variance of Correct Detection Scores

Source	df	Sum of Squares	Mean Square	F
Resolution (A)	1	84.81	84.41	99.30**
Location (B)	8	160.60	20.07	37.86**
Subjects (C)	29	73.11	2.52	--
A x B	8	65.05	8.14	22.61**
A x C	29	24.74	.85	2.36**
B x C	232	124.29	.53	1.47**
A x B x C	232	85.40	.36	--
Total	539	618.00		

** $p < .01$

TABLE 4

Summary of Analysis of Variance of Response Times

Source	df	Sum of Squares	Mean Square	F
Resolution (A)	1	9.97	9.97	45.31**
Location (B)	8	10.67	1.33	11.08**
Subjects (C)	29	33.98	1.71	--
A x B	8	1.39	.17	1.41
A x C	29	6.63	.22	1.83**
B x C	232	28.02	.12	1.00
A x B x C	232	27.87	.12	--
Total	539	118.53		

** $p < .01$

DISCUSSION

The results show that reducing resolution from 800 to 450 lines in both the horizontal and vertical planes significantly reduces the probability of detecting an M-48 tank. Whereas a previous study (4) found no significant differences in target detection between 400 and 800 levels of resolution in the horizontal plane, the present study found significant differences in target detection between 450 and 800 levels, when resolution was varied in both horizontal and vertical planes.

The analysis of variance indicated that all of the interactions were significant for the detection scores, but only the resolution-by-subjects interaction was significant for the response times. Since the primary interest is in the resolution variable, only the resolution-by-location and the resolution-by-subject interactions will be treated graphically for detection scores. Figure 2 presents the resolution-by-location interactions for the number of correct detections. The graph shows that, for locations 2, 5, and 8, Ss perform almost equally well at both levels of resolution, but in other areas, Ss perform much better with the higher level of resolution. Figure 3 presents the resolution-by-subject interactions for the numbers of correct detections. The graph indicates that Ss perform quite differently at different levels of resolution. Figure 4 presents the resolution-by-subjects interaction for the response times. The graph also indicates that Ss perform quite differently at different levels of resolution.

The target's location on the TV screen was also a significant factor in the probability of detecting a target. These results are similar to the results of the previous study (4). The percentage of correct detections for each of the nine areas on the TV screen is graphed in Figure 5. Figure 5 shows that the percentage of correct detections was highest in the upper middle, middle, and lower middle areas of the TV screen. The percentage of correct detections was lowest in the corners of the TV screen. However, the effects of target location are confounded with several other factors. First, Ss use different techniques in scanning visual displays, and the location effect may occur because the middle areas of the TV screen are scanned more frequently than other areas. Second, resolution is not uniform across the surface of the TV monitor. On the small monitor, when the center of the screen has 800 lines of resolution, the level in the corner areas may be as low as 500. On the large monitor, when the center of the screen has a resolution of 450, the corner areas may be as low as 300. Greater degradation in the corner areas of the TV displays might conceivably account for the low percentage of targets detected in these corner areas. Third, TV-screen luminance, as measured with a Pritchard photometer, model 1970-PR, is not identical for both monitors. On the 14-inch monitor, luminance varied from 11.5 foot-Lamberts in the center to 8.0 foot-Lamberts in the corners. With the 21-inch monitor, the luminance varied from 11.0 in the center to 8.5 in the corner areas. It is possible that these differing luminances also contribute to low target-detection probabilities in the corners of the TV screen.

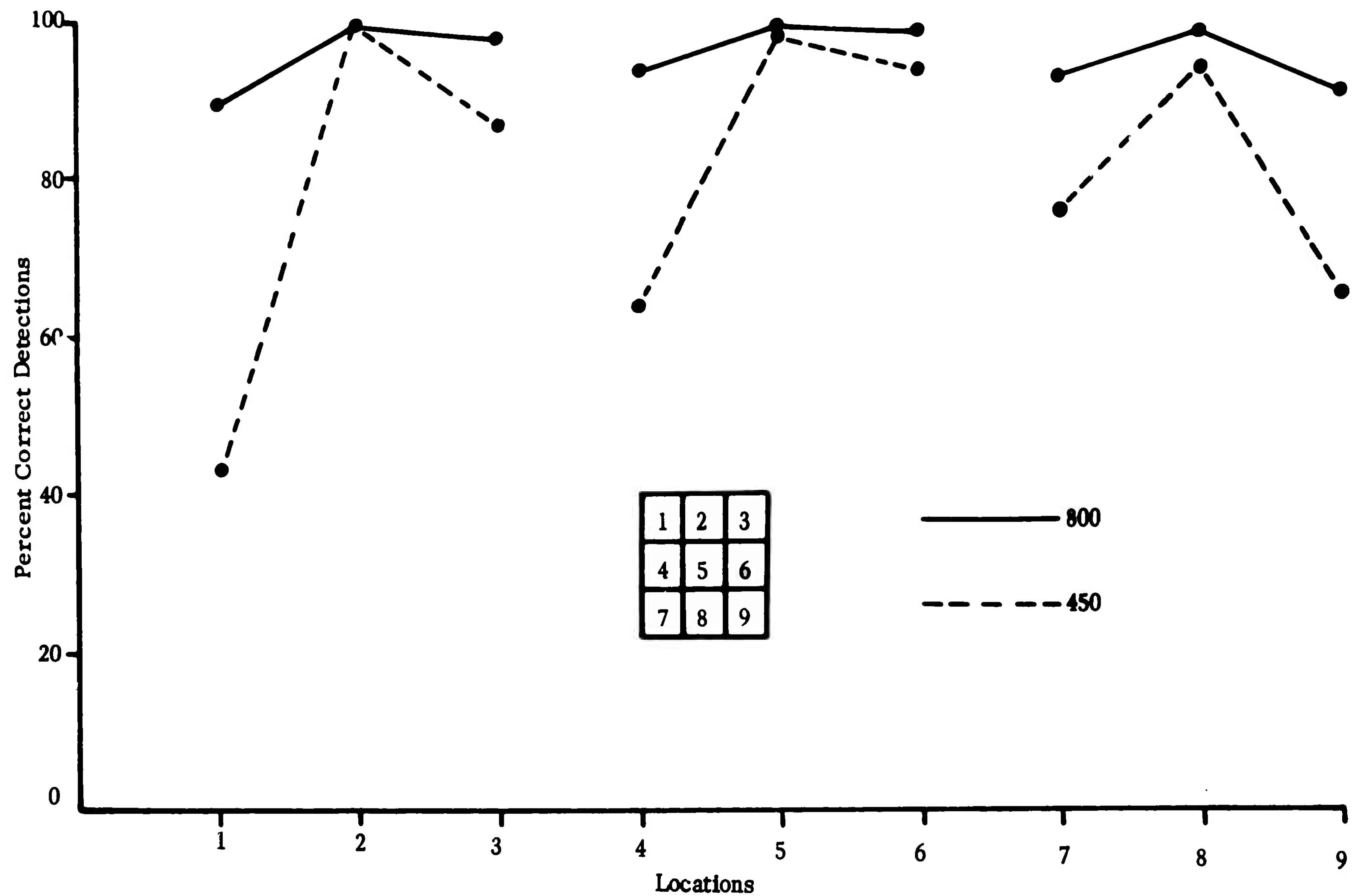


Fig. 2. PERCENT CORRECT DETECTIONS AS A FUNCTION OF RESOLUTION AND LOCATIONS

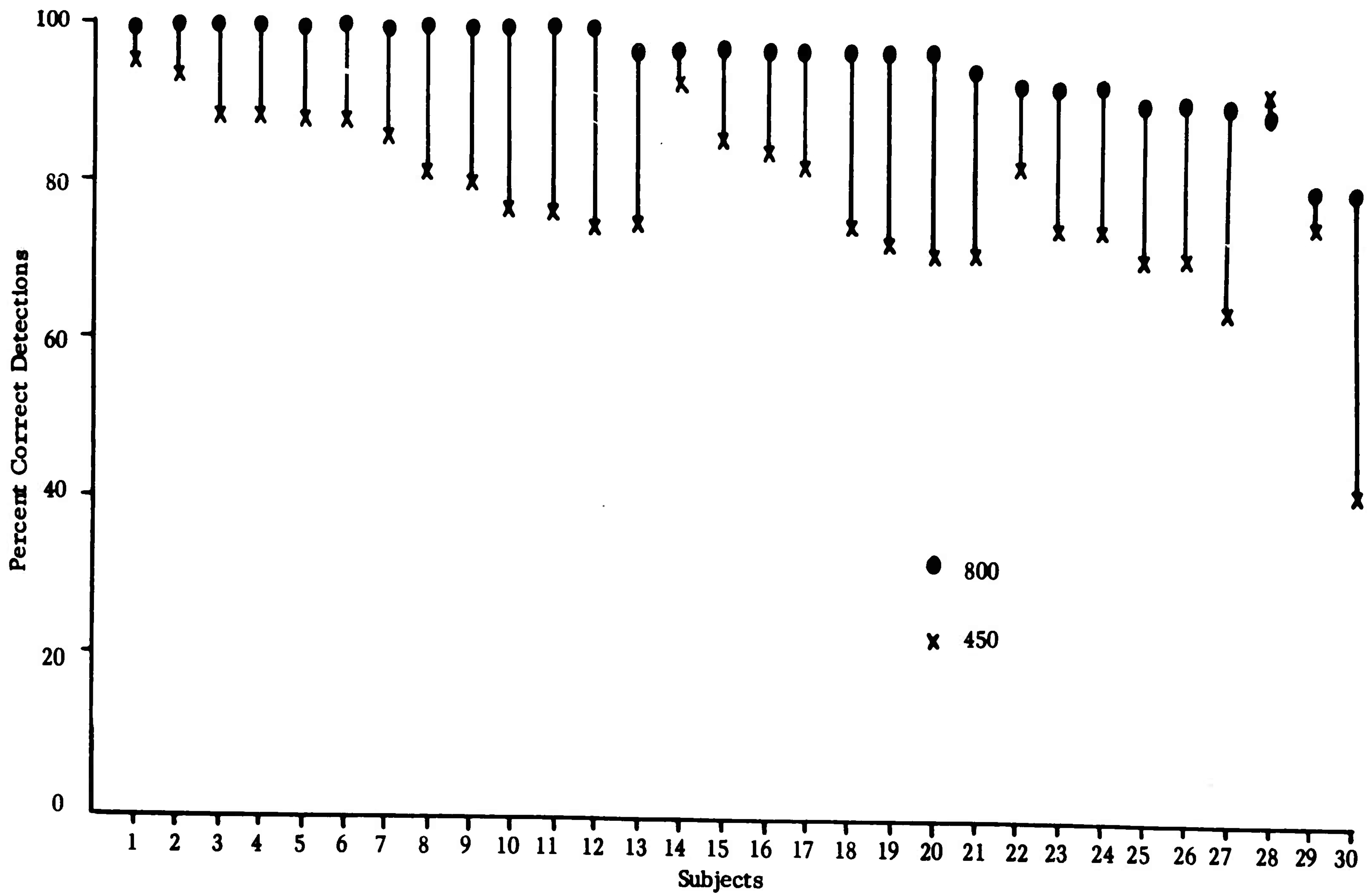


Fig. 3. PERCENT CORRECT DETECTIONS AS A FUNCTION OF RESOLUTION AND SUBJECTS

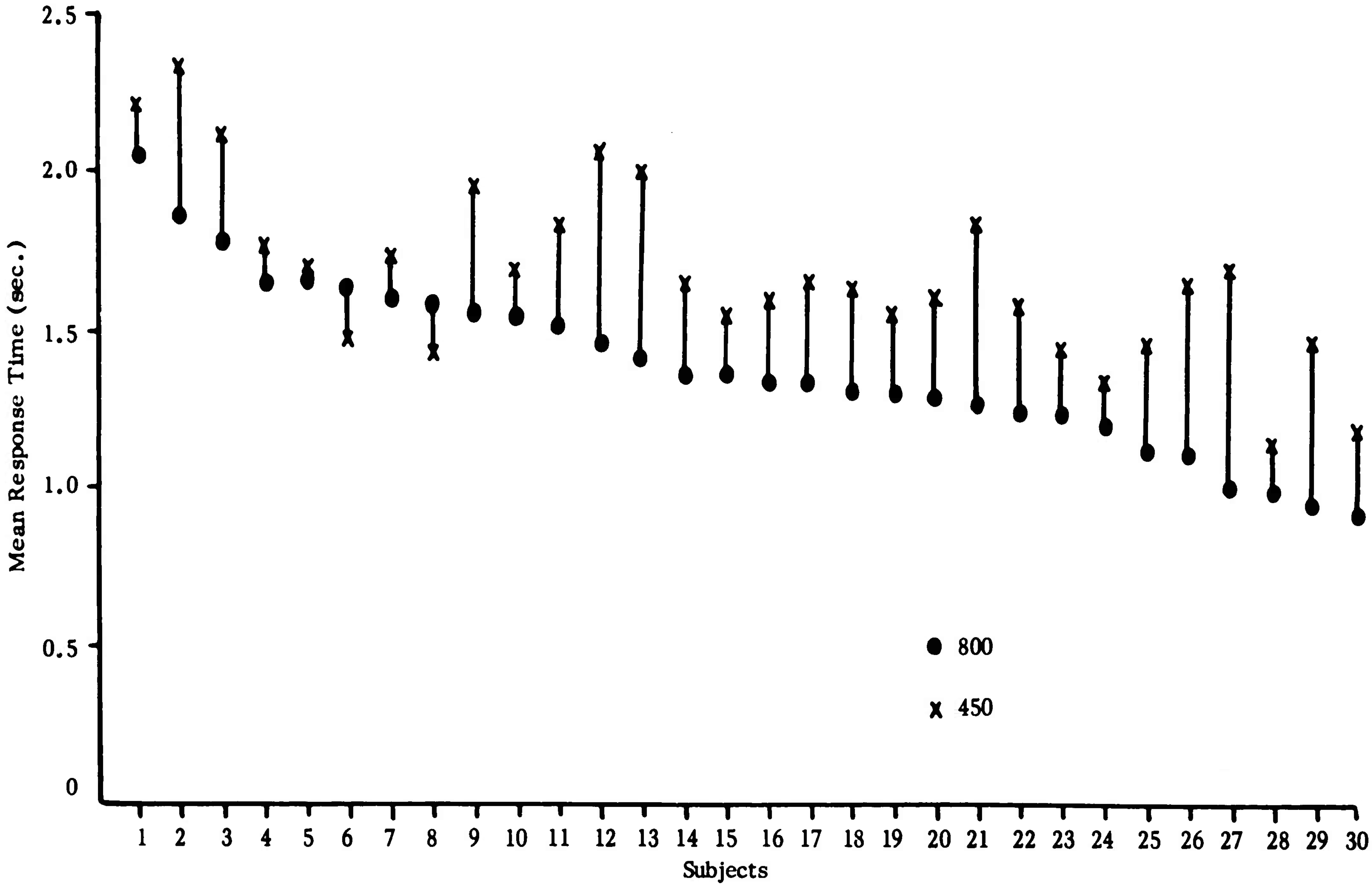


Fig. 4. MEAN RESPONSE TIME AS A FUNCTION OF RESOLUTION AND SUBJECTS

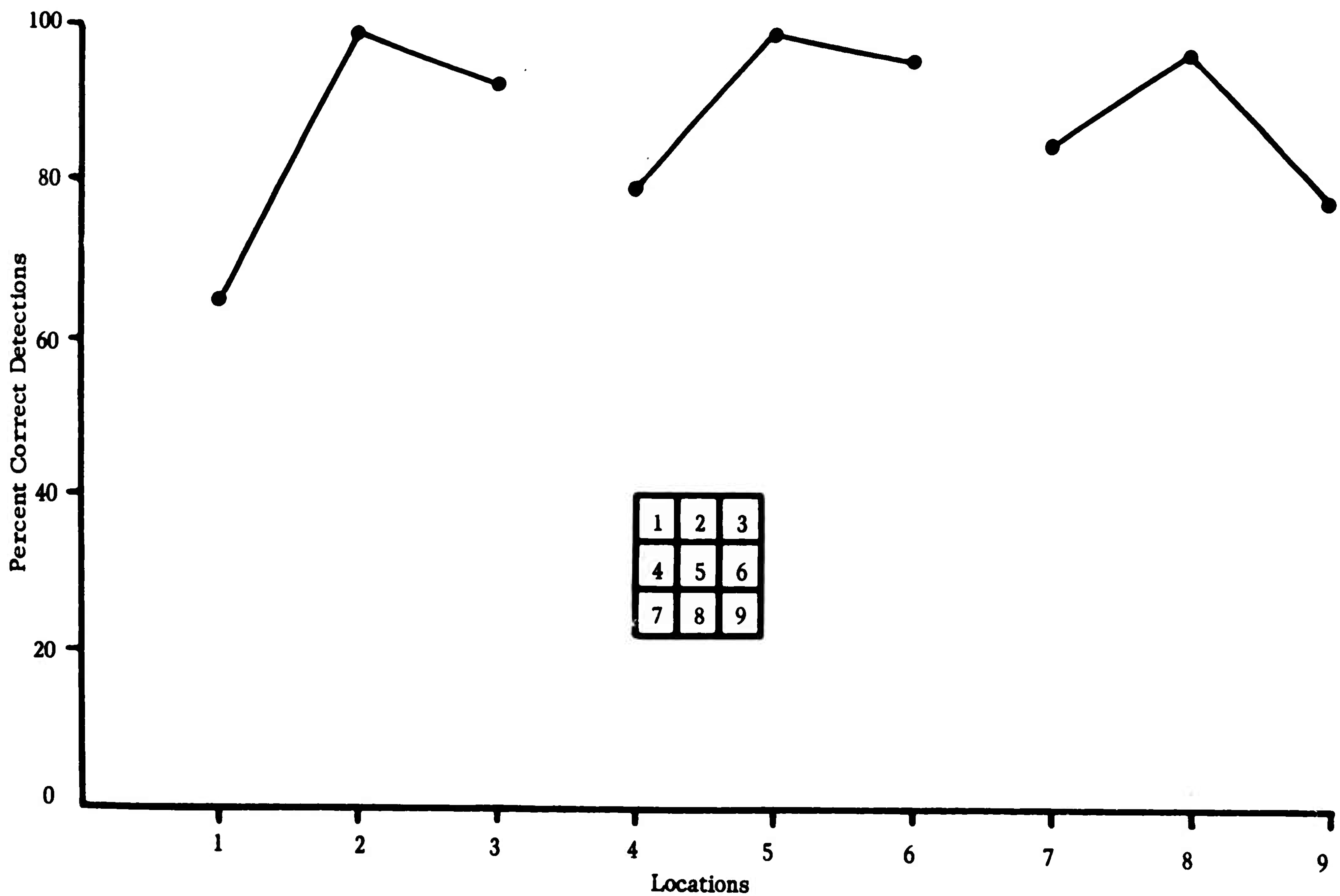


Fig. 5. PERCENT CORRECT DETECTIONS AS A FUNCTION OF LOCATIONS

SUMMARY

This experiment investigated how TV resolution, varied in both the horizontal and vertical planes, affects the probability of detecting targets. Thirty Ss viewed an M-48 tank on a closed-circuit black-and-white TV system at two levels of resolution (800 and 450 lines). The S's task was to indicate in which one of nine areas the tank appeared on the TV screen.

In a previous study which changed horizontal resolution only, changing resolution from 800 to 400 lines did not affect target-detection probabilities significantly. But if resolution is changed in both planes, as in this study, decreasing the resolution from 800 to 450 did significantly reduce the probability of S's detecting a target. The target's location on the TV screen also had a significant effect on target-detection probability, but the effect was confounded with resolution, luminance, and S's search techniques.

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APPENDIX

INSTRUCTIONS TO SUBJECTS

We are going to present a series of pictures on the screen. Each one will be a photograph in which there may be a military target (tank), or the screen may be blank. Here is an example (SLIDE ONE). Can you spot the target? As you see, it is in the ______ grid on the screen. This panel is also marked into nine areas. As soon as you spot the target, press the button that corresponds with the area on the screen where you see the target. Press the button as soon as possible after you spot the target. If the screen does not have a target, push two different buttons (any two). I will say "Ready" before I flash each slide. If the TV fails at any time, notify me through the intercom. Do you have any questions?

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